Inter-Market Overreaction and Investment Strategies

Chulwoo Han[1]
University of Durham
chulwoo.han@durham.ac.uk

Doojin Ryu
Sungkyunkwan University
sharpjin@skku.edu

Abstract

We investigate the relationship between a market's development status and its reaction to a developed market, using the data from the Korean and the US markets. Furthermore, we examine investment strategies based on the market reaction. The reaction to the US market is restrictive at the opening period of the market, but overreaction is observed as the market grows. Maturation of the market and introduction of an overnight futures market erase most of the overreaction. A contrarian investment strategy performs remarkably well during the growth period, but is less robust after the overnight market opens. Nevertheless, investment opportunities can still be sought for during global economic crises.

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1. Introduction

Globalization has connected global markets closely, and there is clear evidence that suggests information transmission between markets. If global capital markets are efficient, shocks from one market will be evaluated and reflected in other markets in a timely manner. A number of studies investigate return co-movement and volatility spillover among capital markets.

Eun and Shim (1989) and Bessler and Yang (2003) observe that information is mutually transmitted between markets; in particular, the US market has the strongest influence on other markets. Lin *et al.* (1994) and Karoly and Stulz (1996) report that the open-to-close return of the NYSE affects the close-to-open return of the Tokyo Stock Exchange. Wongswan (2006) shows that macroeconomic information from developed countries, such as the United States and Japan, is transmitted rapidly to emerging markets, such as Korea and Thailand.

The capital markets of East Asian countries open after the US market is closed. Therefore, under efficient market hypothesis, it is expected that the net effect of the information released in the US market will be completely reflected in the opening price of the East Asian markets and have no effect on the intraday return. However, many studies report contrasting results. Becker *et al.* (1990) show that the daily return of the US market is positively correlated to both the overnight return and the intraday return of the Japanese market the subsequent day. This suggests that the information from the US market is not fully reflected in the opening price of the Japanese market, but rather absorbed slowly during the market opening hours. Becker *et al.* (1990), however, admit that a trading strategy based on their findings is not viable when trading costs are considered. Contrary to Becker *et al.* (1990), Fung *et al.* (2010) find a negative correlation between US market return and subsequent intraday return of the markets of East Asian countries, including Singapore, Korea, Hong Kong, Taiwan, and Japan, during the period of January 1996 to December 2003. They also show that the size of the reversal is proportional to the US market return, and the reversal weakens when there is a gap between the US market closing and the Asian market opening due to factors such as holidays. Finally, they show that the reversal does not occur rapidly at the market opening but progresses steadily until the market closes. Park and Yi (2011) report a similar phenomenon: the US market return is positively correlated with the overnight return and negatively correlated with the intraday return of the Korean market. They attribute this overreaction-reversal to the contrarian trading strategy of individual investors who hold a large portion of the Korean stock market.

Though it seems evident that there exists inefficiency in the process of information transmission between markets, it is not clear if it is significant enough to be exploited to make a profit beyond trading costs. Testing a trading strategy can yield misleading conclusions if trading costs incurred during trading are not treated properly. One example is the contradictory results of Gatev *et al.* (2006) and Do and Faff (2011): Gatev *et al.* (2006)

argue that an annual return of 11% can be achieved through a pairs trading strategy in the US market. However, Do and Faff (2011) refute this conclusion by showing that most profit disappears when commission, short selling costs, and market impact are taken into account. Other interesting studies on the effects of trading costs can be found in Becker *et al.* (1990), Ball *et al.* (1995), Grundy and Martin (2001), Korajczyk and Sadka (2004), and Chan *et al.* (1990).

The Korean market, by opening an overnight futures market in 2009, is uniquely positioned in that trading of the Korean market index futures is possible practically 24 hours a day. The opening hours of the overnight market overlap with the opening hours of the US market except for the last hour, and most information from the US market is transmitted immediately to the overnight market. We hypothesize that opening of the overnight futures market changes the dynamics of the regular market price and mitigates the overreaction-reversal phenomenon.

The aim of this paper is two folds. The first is to address the relationship between the degree of overreaction and the development status of the market. We also investigate how the introduction of the overnight futures market affects the overreaction-reversal of the regular market. Second, we design a trading strategy that exploits the intraday reversal and test if a significant profit can be generated even after direct and indirect trading costs are subtracted. We use KOSPI200 futures as the investment vehicle.

This paper is organized as follows. In Section 2, the Korean stock index futures market is described with some statistics. In Section 3, we confirm the overreaction-reversal of the Korean market to the US market using an extended sample. We also examine the effect of the overnight market in this section. Section 4 is devoted to developing and testing trading strategies based on the intraday reversal. Finally, concluding remarks are given in Section 5.

2. KOSPI200 Futures Market

KOSPI200 is a capitalization-weighted index consisting of the two hundred common stocks with the largest market capitalization listed in the Korea Exchange. This serves as the underlying asset of the KOSPI200 futures; its initial value is set to 100 on January 1, 1990. The KOSPI200 futures market is characterized by low transaction costs and high liquidity compared to the spot market. There is no transaction tax and the brokerage fee is significantly lower than that of the spot market: the fee for futures trading ranges from 0.1bp to 0.9bp, while the fee for spot trading is about ten times higher. It is also the most liquid futures market and has the largest trading volume in the world. These features make the futures an attractive vehicle to implement a trading strategy that invests in the market portfolio.

2.1. Regular Futures Market

The KOSPI200 futures market opened on May 3, 1996 and has grown very quickly, with a daily trading volume of over 38 billion dollars in 2011. The multiplier of the futures contract is 500,000 KRW (approximately 500 dollars) and the tick size is 0.05, *i.e.*, 25,000 KRW. The regular market opens at 9:00 am and closes at 15:05 pm, the pre-opening batch auction runs from 8:00 am to 9:00 am, and the post-market batch auction runs from 3:05 pm to 3:15 pm. There are four different delivery months: March, June, September, and December, and the expiry is the second Thursday of each delivery month. The initial margin is 15.0% of the contract size except for the period between October 11, 2010 and October 7, 2011, during which the initial margin is 13.5%. The maintenance margin is two thirds of the initial margin and the minimum portion of the cash margin is one third of the margin. The rest can be covered by other securities such as stock. The maximum number of contracts that can be ordered at once is limited to 1,000, and the maximum daily price change is $\pm 10\%$.

2.2. Overnight Futures Market

The KOSPI200 overnight futures market opened in September 2009 as a collaboration with the Chicago Mercantile Exchange (CME). Since opening, the trading volume has increased steadily, and now exceeds 10% of the volume of the regular market. The market opens at 6:00 pm after the regular market is closed, and closes at 5:00 am the following day, which is equivalent to 4:00 am to 3:00 pm EST. Therefore, except for the last hour, the futures market and the US stock market are open simultaneously. Daily settlement is made after the regular market is closed, at the closing price of the regular market. The maximum order number is 100 contracts and the maximum daily price change is $\pm 5\%$. With the advent of the overnight futures market, KOSPI200 index futures can practically be traded 24 hours a day.

Table 1 demonstrates the growth of the KOSPI200 index and its futures market since the launch of the futures market. In the table, the third column reports the KOSPI200 index at the end of each year and the forth column is the average daily trading volume of the stocks in KOSPI200. The average daily number of contracts and trading volume of the futures markets are reported in the remainder of the columns. The trading volumes are in US dollars (converted using the daily exchange rate). The futures market has grown very rapidly; the trading volume increased from 0.19 billion dollars in 1996 to 38.59 billion dollars in 2011, overwhelming the size of the spot market volume (5.23 billion dollars). The overnight futures market is also growing fast; in 2012, it was comparable in size to the spot market.

[*TABLE 1 HERE*]

3. Reaction of the Korean Market to the US Market

Fung *et al.* (2010) and Park and Yi (2011) report that the Korean market, when it opens, overreacts to shocks from the US market and that mispricing is corrected during the market opening hours, resulting in a negative correlation between the intraday return and the US market return. We examine their findings over an extended sample period spanning the entire length of time since the KOSPI200 futures market opened, and also investigate if introduction of the overnight futures market causes any structural changes to the dynamics of the regular market price. As proxies for the market portfolio, we choose KOSPI200 for the Korean market and S&P500 for the US market.

The sample consists of data from the opening of the KOSPI200 futures market to the latest data available, *i.e.*, from May 3, 1996 to September 30, 2012. KOSPI200 spot and futures market data are obtained from the Korea Exchange, and the S&P500 index is obtained from CRSP. The overnight call rate, which is later used as the risk free return on the margin account, is available from the Bank of Korea. If only one of the two markets is open, the corresponding data is removed from the sample. For example, the Korean market return on July 5th, the day after Independence Day, is ignored. Similarly, we remove the Monday return of the Korean market before December 8, 1998, as until this time, the Korean market was open on Saturday. During this period, the Friday return of the US market affects the Saturday return of the Korean market, and the Monday return has no matching US market return. Fung *et al.* (2010) coined the term 'calm-down period' to describe the situation when there is a gap between the business days of two markets. That is, weekends and holidays in both countries are calm-down periods. We adopt this term in this article.

We divide the whole sample into three sub-periods: from the beginning of the sample to December 4, 2000, when the Korean government declared its exit from the Asian crisis (Period 1); to November 16, 2009, the opening of the overnight futures market (Period 2); and to the end of the sample

(Period 3). During the first period, the Asian economic crisis prevailed and Korea was under supervision by the IMF. Opening of the Korean capital market accelerated in this period, and we therefore call this period "opening of the capital market". During the second period, the Korean market grew rapidly and the portion of international capital increased significantly, once reaching 40% of the total market capitalization of the KOSPI200 stocks. We call this period "growth of the capital market". In the third period, the trading volume of the regular futures market stabilized, while the trading volume of the overnight market increased significantly. We call this period "maturation of the capital market".

Following Park and Yi (2011), we split the daily return of the S&P500, R_{us}, into quintiles with threshold values of -0.75%, -0.20%, +0.20%, and 0.75%, and calculate the close-to-open return, R_{co}, and the open-to-close return, R_{oc}, of the KOSPI200 futures the subsequent day. We add the return of the KOSPI200 overnight futures, R_{ov}, in Period 3.[2] The results are reported in Table 2. We also report the correlation coefficients between R_{us} and R_{co}, R_{oc}, and R_{ov} in Table 3.

Panel (a) displays results from the whole sample period. We can clearly observe a positive correlation between the US market return and the overnight return of the Korean market. However, relationship between the US market return and the intraday return is not obvious: many of the intraday returns are insignificant and the sign is inconsistent. Period-by-period analysis results, as reported in Panel (b), (c), and (d), reveal more interesting facts. A positive correlation between R_{us} and R_{co} is apparent in every sub-period. However, in Period 1, R_{co} is significant only in the first and the fifth quintiles and the correlation coefficient between R_{us} and R_{co} is 0.348, less than half of those for Period 2 and 3, which are 0.760 and 0.787, respectively. There is also a hint of a positive correlation between R_{us} and R_{oc} in this period: although the values are not significant, R_{oc} has the same sign as R_{us} in most quintiles. This signifies that in the opening period of the capital market, the Korean market was not fully integrated with the global market and information transmission from other countries was rather slow.

A significant negative correlation between R_{us} and R_{oc}, evidence of the overreaction-reversal of the Korean market to the US market, is seen only in Period 2. R_{oc} in quintile 1, 2, and 5 is significantly different from zero

[2]Throughout the article, overnight return refers to the close-to-open return and intraday return to the open-to-close return, both on the futures of the regular market. Overnight futures return refers to the return on the futures of the overnight market.

with the opposite sign of R_{us}, and the correlation coefficient between them is -0.206. This suggests that, during the growth period after the Asian economic crisis, the Korean market became widely exposed to international capital and vulnerable to global economic shocks, sometimes causing irrational overreactions by investors. However, the extent of the overreaction decreases considerably as the market matures, especially after opening of the overnight futures market, because the overnight market absorbs the information released during the night and provides sufficient time for a feedback loop to stabilize any irrational price movement.

Overreaction does not seem to occur after calm-down periods. In all samples, R_{oc} is either insignificant or significant but the sign is counter-intuitive. This could be because investors have enough time to evaluate news from the US market fairly, or because the news is mixed with other news released during the calm-down period.

[*TABLE 2 HERE*]

[*TABLE 3 HERE*]

4. Investment Strategies Based on Overreaction

As demonstrated in the previous section, the Korean market overreacts to shocks from the US market at opening and this overreaction subsides during the market opening hours. In this section, we propose a trading strategy exploiting this market inefficiency and test if a profit can be generated.

4.1. Naive Risky Investment Strategies

We first employ a simple contrarian trading strategy, in which if the US market drops during the night, we buy a KOSPI200 futures contract in the pre-opening batch auction and sell it in the post-market batch auction, and vice versa. We choose the auction so that we can ignore bid-ask spread. The return of the strategy is calculated by the formula

$$\begin{aligned} R &= \frac{F_c(1-f) - F_o(1+f)}{F_o(M+f)} \quad \text{(long position)} \\ R &= \frac{F_o(1-f) - F_c(1+f)}{F_o(M+f)} \quad \text{(short position)} \end{aligned} \tag{1}$$

where F_o and F_c respectively denote the opening and the closing price of the futures contract. The brokerage fee, f, is assumed to be 0.3bp. The margin ratio, M, is set to 15% of the trading volume except for the period of October 11, 2010 to October 7, 2011, in which it is set to 13.5%. Because the reversal is more significant when the US market moves considerably, we test three variations of the strategy. In Strategy 1, we invest considering only the sign of the US market return regardless of its size. In Strategy 2, we invest only when the size of the return exceeds 0.2%, *i.e.*, when the return falls into quintiles 1, 2, 4, or 5. In Strategy 3, we invest only when the return drops below -0.75% (quintile 1) or rises above 0.75% (quintile 5). We assume no trading on the day after a calm-down period because reversal is not significant on these days, as shown in the previous section.

The performance of each strategy is reported in Table 4. Due to the high leverage of the futures contract, the return is extremely high, but also extremely volatile. In all three cases, the final value is over one million times the initial value. The returns are relatively low from 2005 onward, except for 2008, when the global economy went into a recession triggered by the sub-prime mortgage market crash in the United States. In this period, all the global markets reacted extremely sensitively to news from the United States and our contrarian investment strategies enjoy an extremely high return. Since 2009, all three strategies perform poorly experiencing negative returns in most years. This is also illustrated in Figure 1. We hypothesize that this is because introduction of the overnight futures market mitigates overreaction in the regular market.

Among the three strategies, the first strategy offers the most trading opportunities, but the second strategy yields the highest value at the end of the sample period, which means a higher return per trade. The third strategy provides the least investment opportunities, less than half that of the first strategy, but it still achieves a comparably high return and indeed performs best in terms of the Sharpe ratio. The choice between Strategy 2 and 3 is not clear and we compare them under different circumstances later in this section.

[*TABLE 4 HERE*]

[*FIGURE 1 HERE*]

Though the returns are apparently extremely high, these naive strategies are too risky for real world implementation and unrealistic considering the size of the market. We need a more realistic strategy that controls risk within a tolerable level. Before we explore this topic further, we investigate the source of return by running the following regression

$$R = \beta_0 + \beta_1|R_{us}| + \beta_2 D_1|R_{us}| + \beta_3 D_3|R_{us}| + \beta_4 D_{cd}|R_{us}| + e \qquad (2)$$

where R is the return of the contrarian strategy as defined in Equation 1. Dummy variables D_1 and D_3 respectively indicate the sample Period 1 and 3, and D_{cd} indicates the day after a calm-down period. The regression results are reported in Table 5. Except for the dummy for Period 3, which is significant at 5% level, all other variables are significant at 1% level. This suggests that the strategy performs best in the second period, especially when we trade only on normal days avoiding the days immediately after calm-down periods. In fact, trading on the day after a calm-down period is expected to yield a negative return. Though not reported here, we also examine whether the sign or size of R_{us} affect R in a nonlinear fashion by adding additional dummy variables for the sign and quintiles of R_{us}. These variables, however, turn out to be insignificant factors.

[*TABLE 5 HERE*]

4.2. Investment Strategies with Risk Control

Investing entire wealth into the futures market is too risky and unrealistic. A viable strategy essentially needs to control risk within a certain level. Therefore, we modify the naive strategies so that only a portion of the total wealth is invested in the futures and the rest is invested in a risk free asset. The wealth allocated to the futures is managed by the contrarian investment strategy described earlier in this section. If the market condition does not meet the investment criteria of the strategy under consideration, the total wealth is invested in the risk free asset. For example, if the US market return is within the range (-0.75% , 0.75%), no trade takes place in the futures market under Strategy 3. Also, the wealth is entirely invested in the risk free asset the day after a calm-down period.

We consider two allocation methods: the first method involves maximizing long run growth return as proposed by Kelly (1956), while the second method imposes a risk limit defined as Value-at-Risk (VaR). Assuming that the futures return[3] is normally distributed with mean μ and variance σ^2, Kelly ratio can be obtained by solving the following optimization problem

$$\max_{w_0,w_1} E\left[\ln\left(w_0(1+R_f)+w_1(1+R)\right)\right] \tag{3}$$

subject to

$$w_0 + w_1 = 1$$

[3] More precisely, futures return here refers to the return on the futures managed via the contrarian strategy.

where R_f and R are returns on the risk free asset and the futures contract, respectively, and w_0 and w_1 are the portfolio weights of the two assets. The overnight call rate from the Bank of Korea is used as a proxy for the risk free rate. As shown in Merton (1990), the solution has the closed form

$$w_0 = 1 - w_1, \quad w_1 = \frac{\mu - R_f}{\sigma} \tag{4}$$

Under the same normality assumption, VaR of the portfolio at probability level α is given by the following equation

$$VaR = Z_\alpha w_1 \sigma - (w_0 R_f + w_1 \mu) \tag{5}$$

where Z_α is the Z-value at α. If we set the VaR limit to L, the portfolio weights are determined by the equation

$$w_0 = 1 - w_1, \quad w_1 = \frac{L + R_f}{Z_\alpha \sigma + R_f - \mu} \tag{6}$$

Three risk tolerance levels, 2.5%, 5%, and 10% at $\alpha = 0.01$ are applied for simulation.

Trading a large volume in the auction can impact the market, shifting the price in an undesirable direction. Market impact could be minimized by breaking the total volume into smaller volumes and trading them in the regular market through stealth trading.[4] This is supported by Fung *et al.* (2010) and Park and Yi (2011), who note that correction of mispricing due to overreaction does not take place immediately after the market opens but progresses slowly and steadily throughout the market opening hours. Still, as a conservative measure, we consider cases where the price is shifted by 1 or 2 ticks in every trade, and limit the maximum number of contracts to 1,000. The initial wealth is assumed to be 1 billion KRW, which is enough for 50 to 100 futures contracts depending on the price.

To implement the above allocation methods, we need to estimate μ and σ. According to Chopra and Ziemba (1993), estimation error of mean is more critical to optimal portfolio choice than that of variance-covariance. We employ the regression equation in (2) to estimate the mean and the

[4]For details of stealth trading, refer to Barclay and Warner (1993) or Kyle (1985), and for stealth trading in the Korean futures market, refer to Ryu (2012).

variance of the return of the contrarian strategy, *i.e.*,

$$\hat{\mu} = \hat{\beta}_0 + \hat{\beta}_1 |R_{us}| \quad (7)$$

$$\hat{\sigma}^2 = \text{Variance}(R - \hat{\mu}) \quad (8)$$

We omit the calm-down dummy variable as we exclude the day after a calm-down period both from the regression sample and from the trading simulation sample. The period dummies are also unnecessary as we employ a rolling regression method and update the parameters everyday using a sample of 60 trading days prior to the estimation day. μ and σ are estimated independently using a different sample for each strategy; for example, the regression sample for Strategy 3 consists only of the days when R_{us} falls into Q1 or Q5. This approach provides a better forecast of μ and σ because we apply the same criteria for trading simulation.

4.3. Empirical Results

The estimated mean and variance of the contrarian strategy return are reported in Table 6 and displayed in Figure 2. Only Strategy 2 and 3 are tested as they outperform Strategy 1. The first thing to note is the continuous decrease in both mean and variance with time except for the periods of global economic crisis in 2008 and 2011. It can be inferred that, as the market grows, it becomes more efficient, and exploiting mispricing from overreaction becomes more difficult. This also indicates that the overnight futures market, though it certainly helps, is not the decisive factor to the mitigated overreaction.

When Strategy 2 and 3 are compared, Strategy 3 has a slightly higher mean and standard deviation: 0.63% higher (41.2% increase) in mean and 0.88% higher (9.6% increase) in sigma for the entire simulation period. This is consistent with the higher Sharpe ratio reported in Table 4. It is expected from Equation (4) and (6) that the increased μ/σ of Strategy 3 will lead to a bigger w_1 in the Kelly method and the decreased $1/(Z_\alpha \sigma - \mu)$ will lead to a smaller w_1 in the risk limit method.

[*TABLE 6 HERE*]

[*FIGURE 2 HERE*]

The trading simulation results are reported in Table 7, 8, and 9. Panel (a) and (b) contain the investment results of one billion won in Period 2 and 3, respectively, while panel (c) shows the results of investing one billion won in both Period 2 and 3. Accumulation of wealth by each strategy is also visualized in Figure 3 and 4.

We first compare the results across allocation methods, *i.e.*, the Kelly and the risk limit methods. As the results are qualitatively similar, we focus on the results in Table 7, which are obtained under the assumption of no market impact. Under Strategy 2, the average weight of the futures contract ranges from 13.41% to 20.01% in Period 2, and from 7.23% to 67.56% in Period 3, depending on the risk preference. The average weight is in a similar range under Strategy 3, with some variations among allocation methods. Although a higher w_1 is naturally associated with a higher risk tolerance, the reverse is observed when the 5% and the 10% risk limit portfolios are compared. This is because the 10% risk limit portfolio grows faster in Period 1 and is often bounded by the order limit of 1,000 contracts. Since we are investing in futures contracts, the actual exposure to the market is 6.67 times higher[5] and even the most conservative portfolio with 2.5% risk limit allocates 50.8% to the market portfolio in Period 2 and 57.7% in Period 3 under Strategy 3. The portfolio with 10% risk limit earns the highest overall return in most cases but its value can decrease very quickly under adverse market conditions. In contrast, although a more conservative portfolio normally possesses a lower return and volatility, its return can be higher than that of riskier ones when the overreaction is weak, as in Period 3. The Kelly portfolio is comparable to the 5% risk limit portfolio in several aspects. The annual return is sometimes higher and sometimes lower depending on the case. However, the Kelly portfolio has a consistently lower w_1 and the difference increases when the market is unfavorable. This implies that the Kelly method is more agile in timing than the risk limit method. Indeed, comparison of Equation (4) and (6) shows that the Kelly method is more sensitive to μ and σ. Though not reported here, we also test a combined model of Kelly method and the risk limit method, in which VaR of the Kelly portfolio is constrained by a limit. That is, if VaR of the Kelly portfolio exceeds a limit, it is rebalanced so that VaR stays within the limit. In contrast to our expectations, this approach does not improve the performance of the Kelly method and the overall return is lower for all periods.

Next, we compare Strategy 2 and 3. As noted earlier, Strategy 3 has a higher overall μ and σ than Strategy 2. This results in a roughly 5% higher w_1 of the Kelly portfolio under Strategy 3, compensating for the reduced number of trading opportunities. Ignoring the effect of order limit,

[5]The margin rate of 15% corresponds to leverage of 6.67.

w_1 of the risk limit portfolios, as expected, are decreased under Strategy 3. With higher allocation in the risky investment, the Kelly portfolio under Strategy 3 achieves a fairly high return even with the limited number of trading days. Strategy 3, despite its lower overall return, also has a much higher Sharpe ratio compared to Strategy 2, about 3.0 versus 2.2 for the entire period. More importantly, all allocation methods under Strategy 3 maintain a positive return even in Period 3 and the values are significantly higher than those under Strategy 2. The advantage of Strategy 3 is more noticeable when market impact is considered: under the assumption of 2 tick price shift, the annual return is as high as that of Strategy 2 in Period 2 and higher in Period 3, resulting in a higher overall return. In sum, it can be said that Strategy 3 is more robust to changes in market conditions.

With weakened overreaction after the opening of the overnight futures market, most strategies suffer from a low or even negative return in Period 3, and especially when market impact is assumed, none of the strategies we evaluate seems to survive. This may lead to the conclusion that a strategy based on overreaction is not viable in a mature market. However, closer observation of the results exposes an important fact: spikes in the wealth curve around late 2008 and late 2011 are clearly visible in Figure 3 and 4. These two periods correspond to the US sub-prime mortgage crisis and Europe debt crisis, respectively, during which the global market was unstable. This implies that even though there are fewer investment opportunities in a mature market, opportunities still exist during a global crisis.

Finally, when a price shift due to market impact is assumed, the expected return on the futures becomes smaller and so does the weight. This is followed by a lower return on the portfolio. Still, the lowest annual return of Strategy 2 and 3, which mostly comes from the 2.5% risk limit portfolio, is respectively 17.4% and 16.4% under 1 tick shift and 5.6% and 10.3% under 2 tick shift for the entire period. We consider this result to be very encouraging considering the conservativeness of our assumptions.

[*TABLE 7 HERE*]

[*TABLE 8 HERE*]

[*TABLE 9 HERE*]

[*FIGURE 3 HERE*]

[*FIGURE 4 HERE*]

5. Concluding Remarks

In this article, we investigate overreaction of emerging markets to information from the US market, with a focus on the Korean market. Our study distinguishes itself from previous studies in two aspects. We address the relationship between the degree of overreaction and the development status of the market by dividing market status into three periods: opening, growth, and maturation of the market. We also design investment strategies that exploit the overreaction and test if they can generate a significant profit under realistic assumptions.

In the opening period of the Korean capital market, it is only partially integrated with the global market and the impact of the shocks from the US market is restrictive. There is even a hint of underreaction in this period. Once the market gains momentum and enters the growth period, it is widely exposed to international capital and becomes very sensitive to outside information. Overreaction by irrational investors is commonly observed in this period. As the market matures, overreaction mostly disappears except for periods of global economic crisis. The overnight futures market, which functions as a cushion to absorb the shocks from the US market over the night, effectively mitigates overreaction in the regular market.

A contrarian investment strategy that exploits the overreaction phenomenon performs remarkably well during the growth period, but it is not viable after the overnight futures market opens and the regular market becomes more efficient. Nevertheless, investment opportunities can still be sought out during an economic crisis in which the global market becomes unstable. Investment strategies can be improved by carefully choosing trade opportunities; trading only when the US market moves beyond a certain level offers a higher return per trade and a higher Sharpe ratio. Furthermore, more reliable performance can be achieved when the strategy is accompanied by appropriate control of risk. All the strategies we test maintain a positive return under the most conservative market assumptions. The 10% risk limit portfolio performs best during the growth period, but a portfolio with a more conservative risk limit performs better in the mature market with no apparent overreaction.

Our research focuses on the Korean market and thus our findings may not be generalizable to other countries. Applying our methodology to other countries and comparing the results would be a good comparative analysis study to perform. We find that the overnight futures market does affect the regular market. In-depth investigation of the interactions between these two markets must be a fruitful topic for future research.

References

Ball, R., S. P. Kothari, and J. Shanken, 1995. Problems in measuring portfolio performance: An application to contrarian investment strategies. Journal of Financial Economics 38, 79-107.

Barclay, M. J. and J. B. Warner, 1993. Stealth trading and volatility, which trades move prices? Journal of Financial Economics 34, 281-305.

Becker, K. G., J. E. Finnety, and M. Gupta, 1990. The intertemporal relation between the U. S. and Japanese stock markets. The Journal of Finance 45(4), 1297-1306.

Chan, W.H., R. Jha, and M. Kalimipalli, 2009, The economic value of using realized volatility in forecasting future implied volatility. Journal of Financial Research 32, 231-259.

Bessler, D. A. and J. Yang, 2003. The structure of interdependence in international stock markets. Journal of International Money and Finance 22, 261-297.

Chopra, V. and W. T. Ziemba, 1993. The effect of errors in mean, variance and covariance estimates on optimal portfolio choice. Journal of Portfolio Management 19, 6-11.

Do, B. and R. Faff, 2011. Are pairs trading profits robust to trading costs? Working paper.

Eun, C. S. and S. Shim, 1989. International transmission of stock market movements. The Journal of Financial and Quantitative Analysis 24(2), 241-256.

Fung, A. K., K. Lam, and K.M. Lam, 2010. Do the prices of stock index futures in Asia overreact to U.S. market returns? Journal of Empirical Finance 17, 420-440.

Gatev, E., W. N. Goetzmann, and K.G. Rouwenhorst, 2006. Pairs trading: Performance of relative-value arbitrage rule. Review of Financial Studies 19(3), 797-827.

Grundy, B. D. and J. S. Martin, 2001. Understanding the nature of the risks and the source of the rewards to momentum investing. The Review of Financial Studies 14(1), 29-78.

Karoly, A. and R. M. Stulz, 1996. Why do markets move together? An investigation of U.S.-Japan stock return comovements. The Journal of Finance 51(3), 951-986.

Kelly, J., 1956. A new interpretation of information rate. Bell System Technology Journal 35, 917-926.

Korajczyk, R. and R. Sadka, 2004. Are momentum profits robust to trading costs? Journal of Finance 59, 1039-1082.

Kyle, A. S., 1985. Continuous auctions and insider trading. Econometrica 53, 1315-1335.

Lin, W. L., R. F. Engle, and T. Ito, 1994. Do bulls and bears move across borders? International transmission of stock returns and volatility. The Review of Financial Studies 7(3), 507-538.

Merton, R. C., 1990. Continuous time finance. Blackwell Publishers, Cambridge, MA.

Park, C. W. and A. C. Yi, 2011. Mispricing of US shocks in the Korean stock market. Asia-Pacific Journal of Financial Studies 40, 347-376.

Ryu, D., 2012. The effectiveness of the order splitting strategy: An analysis of unique data. Applied Economics Letters 19, 541-549.

Wongswan, J., 2006. Transmission of information across international equity markets. The Review of Financial Studies 19(4), 1157-1189.

Table 1: The growth of the KOSPI200 index and its futures markets. This table reports the growth of the KOSPI200 index and its spot and futures markets during the sample period. The columns under KOSPI200 represent the index value and the volume of the spot market, and the columns under Regular Mkt and Overnight Mkt respectively represent the volumes of the regular futures market and the overnight futures market. Cnt denotes the average daily number of contracts in thousands and Vol denotes the average daily trading volume in billion US dollars. Trading volume is converted from Korean won to US dollar using the exchange rate at the end of each day.

Year	Trading	KOSPI200		Regular Mkt		Overnight Mkt	
	days	Index	Vol	Cnt	Vol	Cnt	Vol
1996.05							
1996	195	67.93	0.23	3.55	0.19		
1997	292	42.34	0.26	10.73	0.37		
1998	292	64.97	0.32	60.21	1.01		
1999	249	130.02	2.10	68.23	2.74		
2000	241	63.35	1.78	80.90	3.13		
2001	246	86.97	1.12	126.72	3.52		
2002	244	79.87	1.67	172.96	6.47		
2003	247	105.21	1.41	247.69	8.95		
2004	249	115.25	1.49	218.77	10.23		
2005	249	177.43	2.22	171.18	11.59		
2006	247	185.39	2.76	182.58	16.69		
2007	246	241.27	4.51	188.70	22.45		
2008	248	146.35	3.92	261.03	22.36		
2009	253	221.86	3.72	321.63	23.44	0.70	0.06
2010	251	271.19	3.97	336.29	33.36	3.78	0.38
2011	248	238.08	5.23	329.70	38.59	15.56	1.73
2012.09	187	262.49	3.41	230.75	25.76	29.16	3.24

Table 2: Overreaction of the Korean market to the US market. This table analyzes the Korean market reaction to information from the US market. N is the number of trading days, R_{us} is the daily return on the S&P500, R_{co} and R_{oc} are the close-to-open and the open-to-close returns on the KOSPI200 futures traded in the regular market, respectively, and R_{ov} is the return on the futures traded in the overnight market. The S&P500 return is split into quintiles with thresholds of -0.75%, -0.20%, 0.20%, and 0.75% and averaged in each quintile. Period 1, 2, and 3 correspond to the opening, growth, and maturation of the Korean market, respectively. The exact dates of each period are described in Section 3. Calm Down denotes the days after a calm-down period and Normal Days denotes the rest of the trading days. * and ** respectively denote 5% and 1% level of significance.

		Q1	Q2	Q3	Q4	Q5	Total
All Days	N	824	660	748	843	865	3940
	R_{us}	-1.67**	-0.45**	0.00	0.45**	1.63**	0.03
	R_{co}	-1.14**	-0.16**	0.01	0.24**	1.07**	0.02
	R_{oc}	0.10	0.14**	0.02	0.00	-0.11*	0.03
Normal Days	N	676	541	621	688	736	3262
	R_{us}	-1.68**	-0.45**	0.00	0.45**	1.63**	0.04*
	R_{co}	-1.14**	-0.17**	-0.02	0.20**	1.05**	0.01
	R_{oc}	0.20**	0.20**	0.00	0.03	-0.18**	0.04
Calm Down	N	148	119	127	155	129	678
	R_{us}	-1.60**	-0.45**	0.01	0.44**	1.60**	-0.02
	R_{co}	-1.13**	-0.12	0.17**	0.40**	1.18**	0.08
	R_{oc}	-0.35**	-0.09	0.09	-0.13	0.31*	-0.05

(a) Whole Period

		Q1	Q2	Q3	Q4	Q5	Total
All Days	N	219	213	163	233	264	1092
	R_{us}	-1.53**	-0.45**	-0.02*	0.46**	1.50**	0.06*
	R_{co}	-1.19**	-0.08	-0.12	0.04	0.92**	-0.04
	R_{oc}	-0.21	0.19	-0.11	0.15	0.14	0.05
Normal Days	N	199	194	150	217	236	996
	R_{us}	-1.49**	-0.46**	-0.02	0.46**	1.48**	0.06*
	R_{co}	-1.12**	-0.10	-0.17	-0.01	0.83**	-0.07
	R_{oc}	-0.08	0.26	-0.21	0.24	0.07	0.07
Calm Down	N	20	19	13	16	28	96
	R_{us}	-1.91**	-0.42**	-0.02	0.52**	1.63**	0.08
	R_{co}	-1.90**	0.12	0.46	0.64	1.70**	0.29
	R_{oc}	-1.53**	-0.43	1.04	-1.04	0.68	-0.24

(b) Period 1

		Q1	Q2	Q3	Q4	Q5	Total
	N	479	338	431	447	457	2152
All	R_{us}	-1.74**	-0.45**	0.01	0.45**	1.72**	0.00
Days	R_{co}	-1.14**	-0.21**	0.05	0.34**	1.20**	0.05
	R_{oc}	0.26**	0.17*	0.07	-0.06	-0.28**	0.03
	N	377	260	338	358	377	1710
Regular	R_{us}	-1.79**	-0.45**	0.01	0.45**	1.74**	0.02
Days	R_{co}	-1.17**	-0.21**	0.01	0.32**	1.22**	0.05
	R_{oc}	0.38**	0.23**	0.08	-0.10	-0.38**	0.03
	N	102	78	93	89	80	442
Calm	R_{us}	-1.54**	-0.45**	0.01	0.43**	1.61**	-0.06
Down	R_{co}	-1.03**	-0.20*	0.19**	0.43**	1.06**	0.04
	R_{oc}	-0.17	-0.04	0.01	0.09	0.19	0.01

(c) Period 2

		Q1	Q2	Q3	Q4	Q5	Total
	N	126	109	154	163	144	696
All	R_{us}	-1.64**	-0.44**	0.00	0.45**	1.57**	0.06
Days	R_{co}	-1.03**	-0.18**	0.04	0.24**	0.96**	0.05
	R_{oc}	0.04	-0.04	0.02	-0.05	-0.01	-0.01
	R_{ov}	-0.88**	-0.10	0.04	0.18**	0.77**	0.03
	N	100	87	133	113	123	556
Normal	R_{us}	-1.66**	-0.43**	-0.01	0.45**	1.58**	0.07
Days	R_{co}	-1.06**	-0.21**	0.06	0.23**	0.97**	0.05
	R_{oc}	0.09	-0.05	0.05	0.03	-0.05	0.01
	R_{ov}	-0.87**	-0.07	0.05*	0.16**	0.77**	0.05
	N	26	22	21	50	21	140
Calm	R_{us}	-1.56**	-0.47**	0.03	0.44**	1.54**	0.03
Down	R_{co}	-0.93**	-0.05	-0.08	0.26**	0.95**	0.04
	R_{oc}	-0.16	0.00	-0.13	-0.22	0.26	-0.09
	R_{ov}	-0.92**	-0.24**	-0.07	0.24**	0.78**	-0.02

(d) Period 3

Table 3: Correlation between the US market and the Korean market. This table reports the correlation coefficients between the S&P500 return and KOSPI200 futures returns for each period. R_{us} is the daily return on the S&P500, R_{co} and R_{oc} are the close-to-open and the open-to-close returns on the KOSPI200 futures traded in the regular market, and R_{ov} is the return on the futures traded in the overnight market. Period 1, 2, and 3 correspond to the opening, growth, and maturation of the Korean market, respectively. The exact dates of each period are described in Section 3. * and ** respectively denote 5% and 1% level of significance.

		R_{co}	R_{oc}	R_{ov}
Whole Period	R_{us}	0.557**	-0.112**	
Period 1	R_{us}	0.348**	-0.023	
Period 2	R_{us}	0.760**	-0.206**	
Period 3	R_{us}	0.787**	-0.045	0.708**

Table 4: Performance analysis of naive risky investment strategies. This table reports the annual return and the year end value of the three portfolios investing purely in the KOSPI200 futures with an initial value of 1. The investment strategies are described in detail in Section 4. Avg$(R - R_f)$ and Std$(R - R_f)$ are the average and the standard deviation of the annualized daily excess return, respectively, and the Sharpe Ratio is the ratio of these two values. Avg$(R - R_f)$ and Std$(R - R_f)$ are in percentages while Annual Return is not.

	Strategy 1		Strategy 2		Strategy 3	
	Annual Return	EOY Value	Annual Return	EOY Value	Annual Return	EOY Value
2000.12						
2000	1.96	2.96	1.96	2.96	1.21	2.21
2001	21.02	65.27	19.14	59.70	24.36	56.03
2002	24.92	1.69e3	9.35	6.18e2	32.49	1.88e3
2003	8.05	1.53e4	15.56	1.02e4	8.45	1.77e4
2004	15.16	2.48e5	13.18	1.45e5	1.78	4.93e4
2005	5.53	1.62e6	3.94	7.17e5	0.83	9.00e4
2006	0.31	2.13e6	2.36	1.70e6	0.01	9.09e4
2007	0.20	2.55e6	1.43	4.11e6	0.84	1.67e5
2008	48.70	1.27e8	29.93	1.27e8	18.36	3.24e6
2009	-0.60	5.12e7	-0.53	5.96e7	-0.33	2.17e6
2010	-0.18	4.21e7	-0.13	5.18e7	-0.07	2.02e6
2011	-0.49	2.13e7	0.08	5.58e7	0.57	3.18e6
2012.09	-0.56	9.27e6	-0.36	3.55e7	-0.02	3.11e6
Trading Days	2266		1795		977	
Avg$(R - R_f)$	277.50		352.50		507.50	
Std$(R - R_f)$	145.62		152.11		164.44	
Sharpe Ratio	1.91		2.32		3.09	

Table 5: Regression analysis of the contrarian strategy return. This table reports the regression results of the contrarian strategy return on the S&P500 return. The contrarian strategy is described in Section 4. The regression equation has the form

$$R = \beta_0 + \beta_1|R_{us}| + \beta_2 D_1|R_{us}| + \beta_3 D_3|R_{us}| + \beta_4 D_{cd}|R_{us}| + e$$

where dummy variables D_1 and D_3 respectively indicate the sample period 1 and 3, and D_{cd} indicates the day after a calm-down period. The values in parentheses are p-values.

Intercept	$\lvert R_{us}\rvert$	$D_1\lvert R_{us}\rvert$	$D_3\lvert R_{us}\rvert$	$D_{cd}\lvert R_{us}\rvert$	R^2	adj.R^2	F value
0.017	1.349	-1.235	-0.961	-1.780	0.013	0.012	12.91
(0.948)	(0.000)	(0.000)	(0.022)	(0.000)			(0.000)

Table 6: Mean-variance estimation of the contrarian strategies. The mean and variance are estimated from the equations

$$\hat{\mu} = \hat{\beta}_0 + \hat{\beta}_1 |R_{us}|, \quad \hat{\sigma}^2 = \text{Variance}(R - \hat{\mu})$$

Parameters are updated everyday using a sample of 60 trading days prior to the estimation day. Column $\hat{\mu}$ and $\hat{\sigma}$ are average daily values expressed in percentages. Days refers to the number of trading days in each period.

	Strategy 2			Strategy 3		
	$\hat{\mu}$	$\hat{\sigma}$	Days	$\hat{\mu}$	$\hat{\sigma}$	Days
2000.09						
2000	5.05	15.78	12	3.17	16.35	9
2001	3.97	12.07	160	4.92	12.97	97
2002	2.27	12.31	164	4.01	11.30	115
2003	2.14	9.54	159	3.15	10.56	90
2004	2.28	8.52	137	2.33	7.53	57
2005	1.67	7.32	147	1.89	7.13	52
2006	0.83	7.46	132	0.72	7.70	39
2007	0.54	7.20	134	0.41	7.88	66
2008	2.91	10.73	172	3.32	11.63	123
2009	0.10	11.46	172	-0.09	13.22	114
2010	-0.08	5.72	146	0.69	6.10	72
2011	0.80	8.38	158	1.12	8.35	102
2012.09	-0.26	6.14	102	0.42	7.53	41
Period 2	1.95	9.88	1372	2.56	10.82	754
Period 3	0.18	6.84	423	0.84	7.43	223
Period 2-3	1.53	9.16	1795	2.17	10.04	977

Table 7: Investment performance under risk control: 0 tick shift. This table compares investment results of different allocation methods described in Section 4, under no market impact assumption. Kelly denotes a portfolio managed by the Kelly method, and 2.5%, 5.0%, and 10% refer to portfolios with 99% VaR limit of these values. The initial wealth is assumed to be 1 billion wons and EOP value is the end of period value. Order limit is the number of days that hit the order limit (1000 contracts). w_1 is the average weight on the futures contract. Avg($R - R_f$) and Std($R - R_f$) are the average and the standard deviation of the annualized daily excess return, respectively, and the Sharpe Ratio is the ratio of these two values. Annual return, w_1, Avg($R - R_f$), and Std($R - R_f$) are in percentages.

	Strategy 2				Strategy 3			
	Kelly	2.5%	5.0%	10.0%	Kelly	2.5%	5.0%	10.0%
EOP value	161.68	22.44	161.52	212.57	93.24	9.60	63.36	137.94
Annual return	76.51	41.56	76.49	81.99	65.98	28.75	58.97	73.41
Trading days	1372	1372	1372	1372	754	754	754	754
Order limit	512	0	693	1082	259	0	17	585
w_1	15.53	13.41	20.01	18.59	20.26	12.33	24.40	23.05
Avg($R - R_f$)	95.36	54.24	93.37	101.72	152.39	69.03	137.49	166.13
Std($R - R_f$)	38.01	19.61	31.61	40.86	44.66	19.99	39.17	45.74
Sharpe ratio	2.51	2.77	2.95	2.49	3.41	3.45	3.51	3.63

(a) Period 2

	Strategy 2				Strategy 3			
	Kelly	2.5%	5.0%	10.0%	Kelly	2.5%	5.0%	10.0%
EOP value	0.69	1.02	0.94	0.70	1.02	1.23	1.39	1.59
Annual return	-11.99	0.78	-2.27	-11.60	0.84	7.50	12.10	17.49
Trading days	423	423	423	423	223	223	223	223
Order limit	0	0	0	0	0	0	0	0
w_1	7.23	16.97	33.89	67.56	12.76	16.42	32.78	65.45
Avg($R - R_f$)	-21.33	-0.21	-0.45	2.20	3.03	18.99	37.83	73.99
Std($R - R_f$)	26.10	18.27	36.47	72.50	35.34	19.10	38.13	75.94
Sharpe ratio	-0.82	-0.01	-0.01	0.03	0.09	0.99	0.99	0.97

(b) Period 3

	Strategy 2				Strategy 3			
	Kelly	2.5%	5.0%	10.0%	Kelly	2.5%	5.0%	10.0%
EOP value	155.11	22.95	174.08	227.96	104.23	11.81	84.01	162.68
Annual return	53.24	30.36	54.75	58.32	48.17	23.24	45.49	53.86
Trading days	1795	1795	1795	1795	977	977	977	977
Order limit	611	0	1116	1505	314	0	216	808
w_1	12.83	14.25	17.78	16.10	17.75	13.26	24.16	20.44
Avg($R - R_f$)	71.63	41.41	71.81	78.05	119.32	57.61	112.70	131.24
Std($R - R_f$)	33.56	19.35	28.27	36.06	40.04	19.83	36.66	40.84
Sharpe ratio	2.13	2.14	2.54	2.16	2.98	2.91	3.07	3.21

(c) Period 2 and 3

Table 8: Investment performance under risk control: 1 tick shift. This table compares investment results of different allocation methods described in Section 4, under 1 tick price shift assumption. Kelly denotes a portfolio managed by the Kelly method, and 2.5%, 5.0%, and 10% refer to portfolios with 99% VaR limit of these values. The initial wealth is assumed to be 1 billion wons and EOP value is the end of period value. Order limit is the number of days that hit the order limit (1000 contracts). w_1 is the average weight on the futures contract. Avg$(R - R_f)$ and Std$(R - R_f)$ are the average and the standard deviation of the annualized daily excess return, respectively, and the Sharpe Ratio is the ratio of these two values. Annual return, w_1, Avg$(R - R_f)$, and Std$(R - R_f)$ are in percentages.

	Strategy 2				Strategy 3			
	Kelly	2.5%	5.0%	10.0%	Kelly	2.5%	5.0%	10.0%
EOP value	34.93	7.97	40.75	132.56	22.92	5.45	20.80	93.46
Annual return	48.74	26.09	51.32	72.64	41.90	20.85	40.37	66.02
Trading days	1372	1372	1372	1372	754	754	754	754
Order limit	10	0	7	949	9	0	0	521
w_1	15.90	13.01	25.95	27.45	19.44	11.97	23.89	30.56
Avg$(R - R_f)$	67.76	35.22	70.38	96.60	106.30	50.07	100.20	157.14
Std$(R - R_f)$	39.05	18.99	37.87	48.67	46.22	19.37	38.66	53.73
Sharpe ratio	1.74	1.85	1.86	1.98	2.30	2.59	2.59	2.92

(a) Period 2

	Strategy 2				Strategy 3			
	Kelly	2.5%	5.0%	10.0%	Kelly	2.5%	5.0%	10.0%
EOP value	0.68	0.84	0.63	0.32	0.95	1.11	1.13	1.05
Annual return	-12.81	-5.95	-14.71	-32.70	-1.87	3.59	4.23	1.88
Trading days	423	423	423	423	223	223	223	223
Order limit	0	0	0	0	0	0	0	0
w_1	5.36	16.63	33.21	66.24	9.78	16.09	32.13	64.17
Avg$(R - R_f)$	-23.36	-11.98	-23.76	-44.86	-6.68	7.01	14.12	27.09
Std$(R - R_f)$	24.24	17.90	35.75	71.11	32.46	18.69	37.33	74.45
Sharpe ratio	-0.96	-0.67	-0.66	-0.63	-0.21	0.38	0.38	0.36

(b) Period 3

	Strategy 2				Strategy 3			
	Kelly	2.5%	5.0%	10.0%	Kelly	2.5%	5.0%	10.0%
EOP value	26.49	6.68	26.84	121.72	22.48	6.03	23.42	104.24
Annual return	31.96	17.44	32.10	50.13	30.14	16.42	30.59	48.17
Trading days	1795	1795	1795	1795	977	977	977	977
Order limit	14	0	14	1372	13	0	0	744
w_1	13.33	13.86	27.63	24.26	17.18	12.91	25.77	27.58
Avg$(R - R_f)$	47.59	24.10	48.71	72.16	81.05	40.24	80.55	123.10
Std$(R - R_f)$	35.36	18.78	37.39	43.25	42.80	19.24	38.41	48.25
Sharpe ratio	1.35	1.28	1.30	1.67	1.89	2.09	2.10	2.55

(c) Period 2 and 3

Table 9: Investment performance under risk control: 2 tick shift. This table compares investment results of different allocation methods described in Section 4, under 2 tick price shift assumption. Kelly denotes a portfolio managed by the Kelly method, and 2.5%, 5.0%, and 10% refer to portfolios with 99% VaR limit of these values. The initial wealth is assumed to be 1 billion wons and EOP value is the end of period value. Order limit is the number of days that hit the order limit (1000 contracts). w_1 is the average weight on the futures contract. Avg$(R - R_f)$ and Std$(R - R_f)$ are the average and the standard deviation of the annualized daily excess return, respectively, and the Sharpe Ratio is the ratio of these two values. Annual return, w_1, Avg$(R - R_f)$, and Std$(R - R_f)$ are in percentages.

	Strategy 2				Strategy 3			
	Kelly	2.5%	5.0%	10.0%	Kelly	2.5%	5.0%	10.0%
EOP value	6.50	3.03	5.88	12.56	5.93	3.19	7.23	27.33
Annual return	23.26	13.17	21.89	32.67	22.01	13.86	24.74	44.72
Trading days	1372	1372	1372	1372	754	754	754	754
Order limit	0	0	0	0	0	0	0	25
w_1	11.47	12.63	25.21	50.31	14.64	11.63	23.21	46.05
Avg$(R - R_f)$	35.02	17.45	34.65	68.79	58.82	32.25	64.64	129.21
Std$(R - R_f)$	33.20	18.41	36.76	73.41	40.14	18.80	37.53	74.01
Sharpe ratio	1.05	0.95	0.94	0.94	1.47	1.72	1.72	1.75

(a) Period 2

	Strategy 2				Strategy 3			
	Kelly	2.5%	5.0%	10.0%	Kelly	2.5%	5.0%	10.0%
EOP value	0.68	0.70	0.44	0.15	0.90	1.00	0.92	0.71
Annual return	-12.63	-11.71	-25.17	-48.21	-3.45	-0.02	-2.84	-11.21
Trading days	423	423	423	423	223	223	223	223
Order limit	0	0	0	0	0	0	0	0
w_1	4.08	16.30	32.56	64.97	7.22	15.78	31.50	62.93
Avg$(R - R_f)$	-23.40	-22.76	-46.13	-89.97	-12.73	-4.46	-8.71	-18.02
Std$(R - R_f)$	22.59	17.54	35.05	69.78	29.84	18.36	36.60	73.03
Sharpe ratio	-1.04	-1.30	-1.32	-1.29	-0.43	-0.24	-0.24	-0.25

(b) Period 3

	Strategy 2				Strategy 3			
	Kelly	2.5%	5.0%	10.0%	Kelly	2.5%	5.0%	10.0%
EOP value	4.41	2.12	2.56	1.90	5.36	3.19	6.66	22.92
Annual return	13.39	6.55	8.29	5.60	15.27	10.32	17.40	30.35
Trading days	1795	1795	1795	1795	977	977	977	977
Order limit	0	0	0	0	0	0	0	113
w_1	9.73	13.49	26.94	53.76	12.95	12.58	25.10	49.04
Avg$(R - R_f)$	21.26	7.98	15.61	31.38	42.49	23.87	47.90	98.73
Std$(R - R_f)$	31.06	18.24	36.42	72.67	38.07	18.71	37.35	72.40
Sharpe ratio	0.68	0.44	0.43	0.43	1.12	1.28	1.28	1.36

(c) Period 2 and 3

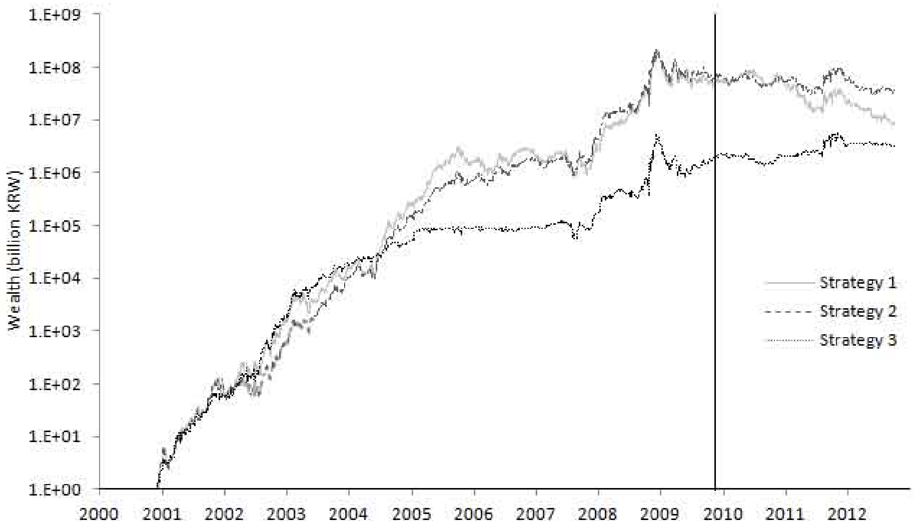
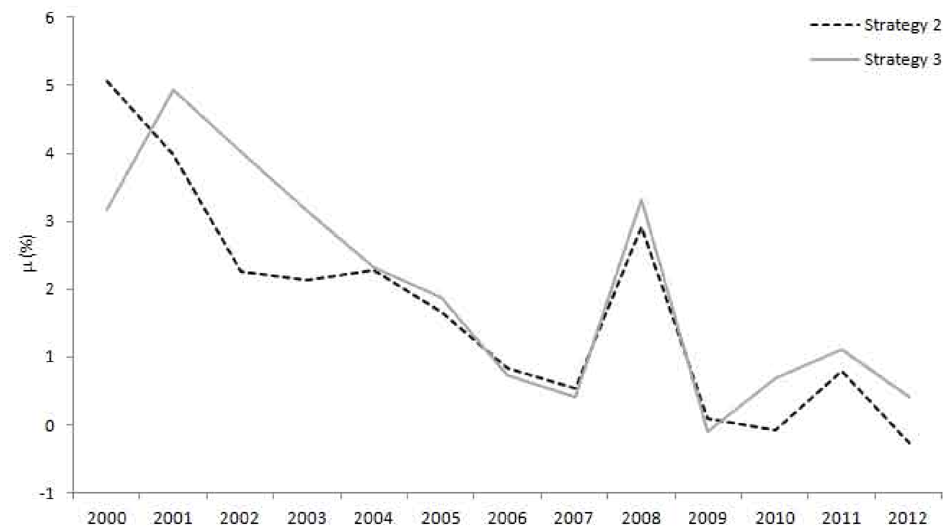
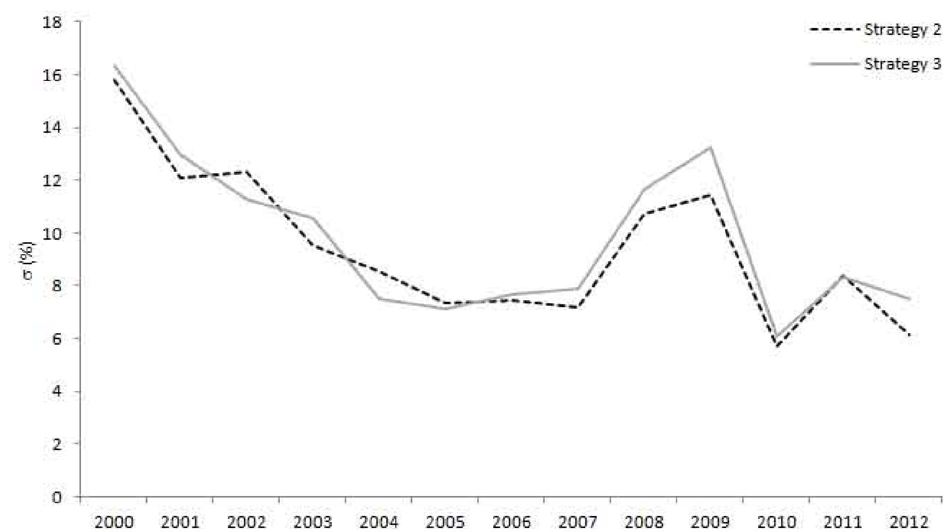


Figure 1: Accumulation of wealth by naive risky investments.

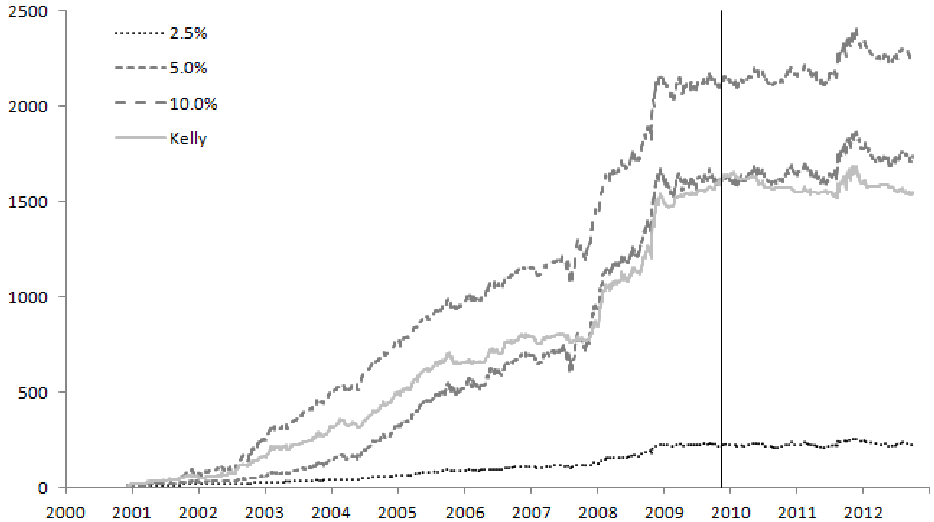


(a) Mean

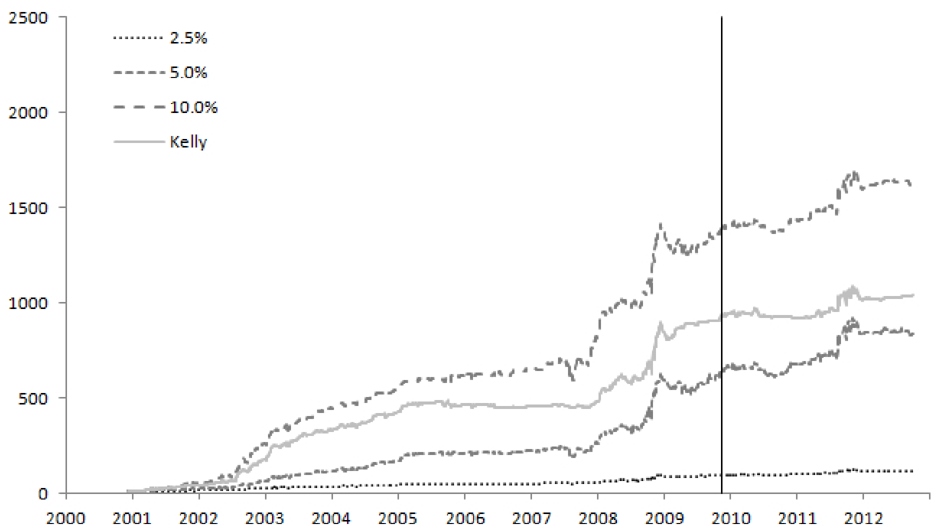


(b) Variance

Figure 2: Estimated mean and variance of the contrarian strategies.

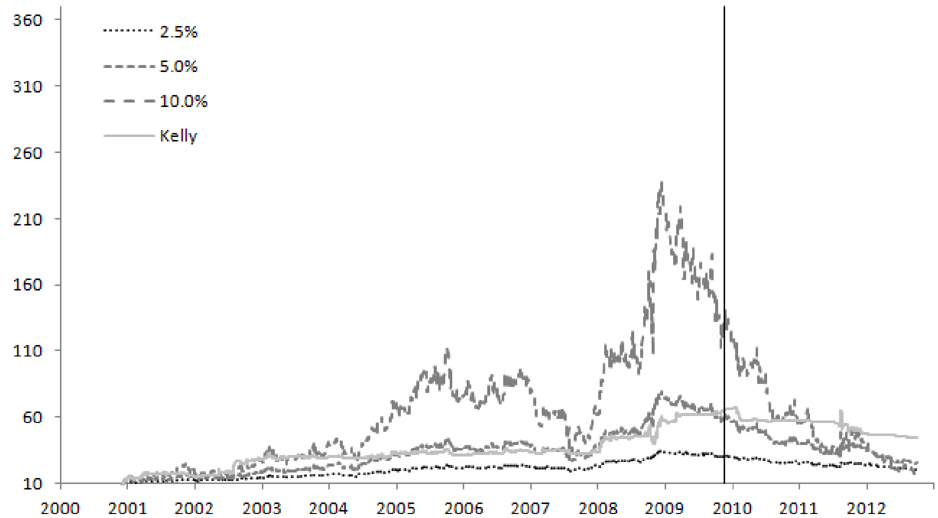


(a) Strategy 2

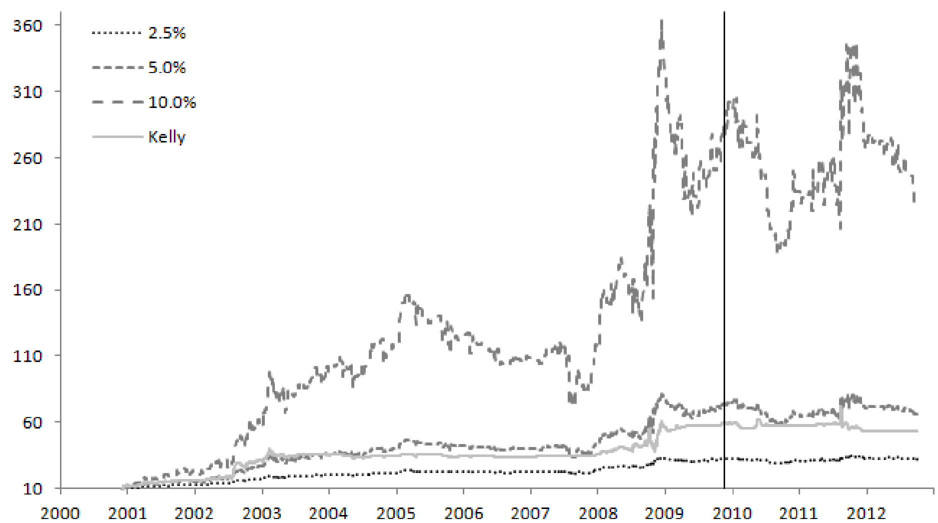


(b) Strategy 3

Figure 3: Accumulation of wealth under risk control: 0 tick shift.



(a) Strategy 2



(b) Strategy 3

Figure 4: Accumulation of wealth under risk control: 2 tick shift.